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The Incidence and Risk Factors of Postoperative Pulmonary Complications in Restrictive Pulmonary Disorders

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Abstract

Postoperative Pulmonary Complications (POPCs) are major causes of morbidity and mortality particularly within the first postoperative week. The reported incidence ranges from 5% to 80%, depending on the patient population, the type of surgery, the presence of risk factors and the definitions used. It has been estimated that more than 1 million POPCs occur annually in the United States (US), within 46,200 related deaths and 4.8 million additional hospitalization days.

Keywords: Postoperative pulmonary complications; Restrictive pulmonary disorders; Incidence; Risk factors; Arterial partial oxygen pressure

Abbreviations

ACCP: American College of Chest Physicians; ASA: American Society of Anesthesiologists; COPD: Chronic obstructive pulmonary disease; CXR: Chest X-ray; ERS/ATS: European Respiratory Society/American Thoracic Society; FEV1: Forced Expiratory Volume in First Second; FVC: Forced Vital Capacity; PaO_2: Arterial partial oxygen pressure; PCO_2: Arterial Partial Carbondioxide Pressure; PFT: Pulmonary Function Test; POPC: Postoperative Pulmonary Complications; TLCO: The Transfer Factor of the Lung for Carbon Monoxide; US: United States

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Introduction

Owing to the reason that POPCs contribute to significant mortality and morbidity, current research focused on evaluating the potential risk factors. Several reports showed numerous modifiable and non modifiable risk factors to date. The well known risk factors are age, male gender, smoking, American Society of Anesthesiologists (ASA) physical status, acute respiratory infection, comorbidities, type of surgery, intraoperative ventilation strategies and several laboratory testing including Pulmonary Function Tests (PFTs). Within the light of these factors, many risk prediction models have been developed [1,2].

Actually, investigating PFTs at the preoperative period is not novel [3,4]. A number of previous reports focused on obstructive PFTs as a risk factor of POPCs. Although surgical and anesthesiologic techniques improved, the risk of POPCs in obstructive patients (mainly asthma and Chronic Obstructive Pulmonary Disease (COPD)) is approximately 9% [5]. The American College of Chest Physicians (ACCP) guidelines recommends preoperative PFTs with a previous diagnosis of COPD or asthma [6]. However, according to best of our knowledge, there is no previous report which specifically indicates the incidence and risk factors of POPCs in restrictive pulmonary disorders. The aim of this study was to evaluate the frequency and the risk factors of POPCs in patients with restrictive pulmonary impairment.

Methods

Study population & design

This is a prospective descriptive study. We enrolled the adult patients that have been consulted preoperatively to our department in case of any of respiratory symptoms and/or PFT abnormality and/or abnormal Chest X-Ray (CXR) and/or known respiratory disorders between May 15th, 2015 to May 15th, 2016. During the enrolment period 72,922 surgeries were performed in Cukurova

University Balcalı Hospital (Adana, Turkey). 45,571 of the operations were performed under local anesthesia, so they were excluded. From the remaining 2,177 preoperative consultations, 60 of them (2.8%) met restrictive PFTs criteria and all of them were enrolled in the study after assignment of the written informed consent. The study flow chart was presented in Figure 1. The institutional ethics committee approved the study (2015/42) and written informed consents were obtained from all of the participants.

Study protocol

At the first visit the detailed clinical examination and radiographic evaluation and if required, further diagnostic tests were performed to find out the reason of restrictive PFTs. At the second visit before the operational procedure, the following data were collected; gender, age, known comorbidities and respiratory disorders, prior medications, smoking history, detailed respiratory symptom history, physical examination and ASA physical status, cardiopulmonary risk index and PFT results were recorded. All patients with restrictive PFTs were further evaluated and the reason of restriction was noted. Inhaled bronchodilators, antibiotics and appropriate treatments implanted as needed. The third visit was performed within the first 24 h of post-operational period, and the duration of operation, the site of surgery, the type of surgery (laparoscopic *vs.* open), vital findings including preoperative oxygen saturation and the arterial blood gas analysis were recorded. The patient was evaluated again before discharge and later on the 7th and 30th postoperative day for the presence of any POPCs. All follow up was performed by the same investigator. Standardized definitions explained below were used for the diagnosis of any POPCs.

PFTs

PFTs were performed by using a calibrated Sensor Medics V-Max 20 Spirometer. None of the patients were receiving oral or inhaled short acting beta 2 agonists 8 h before testing. Baseline Forced Expiratory Volume in first second (FEV1) and Forced Vital Capacity (FVC) was measured 3 times and the best of three measurements was recorded. Total lung capacity was measured using the helium dilution technique (Jaeger MS-PFT Analyser Unit). The transfer factor of the lung for carbon monoxide (TLCO) was measured using the single breath method. The results were presented as the percentages of predicted.

Definitions

Restrictive PFTs: Restrictive pattern was defined as a reduced FEV1 and/or FVC with a normal or increased FEV1/FVC ratio along with the decline of lung volumes and diffusing capacity [7].

Postoperative pulmonary complications: European perioperative clinical outcome definitions have been used in the diagnosis of POPCs [8]. Early POPCs are defined as the POPCs observed within the first 7 day after surgery and late POPCs are defined as the POPCs observed within the first 30 days after surgery.

End points

The main end point of this study was the incidence of POPCs in patients with restrictive PFTs within the first 7th and 30th postoperative days. Secondary outcome was evaluating the potential risk factors of POPCs in restrictive disorders. Additional clinical outcomes including length of hospital stay and mortality was also analyzed.

Statistical analysis

All analyses were performed using SPSS 18.0 statistical software package. Categorical variables were expressed as numbers and percentages, whereas continuous variables were summarized as mean and standard deviation and as median and minimum-maximum where appropriate. Chi-square test was used to compare categorical variables between the groups. The normality of distribution for continuous variables was confirmed with the Kolmogorov-Smirnov test. For comparison of continuous variables between two groups, the Student's t-test was used. For comparison of more than two groups, one-way ANOVA was used. To evaluate the correlations between measurements, Pearson Correlation Coefficient was used. The statistical level of significance for all tests was considered to be 0.05.

Results

2,117 patients were evaluated preoperatively and 60 of them (2.8%) had restrictive pattern. The basic clinical and demographic characteristics of the study group are presented in Table 1. The half of surgeries was laparoscopic. 36 (60%) of surgeries was thoracic, 10 (16.7%) was upper abdominal, 3 (5%) was lower abdominal and 11 (18.3%) was other surgeries. Mean surgery duration was 1.7 ± 1.4 h.

Table 1: The basic preoperative clinical and demographic characteristics of the study group.

Gender	
Female (n %)	24 (40.0%)
Age (years) (mean ± SD)	50.2 ± 15.4
Smoking index, pack-years (mean ± SD)	22.7 ± 30.7
Current smokers (within the last 8 weeks) (n %)	26 (43.3%)
Respiratory symptoms	
Dyspnea (n %)	33 (55%)
Cough (n %)	22 (36.7%)
Phlegm (n %)	8 (13.3%)
Chest pain (n %)	15 (25.0%)
Hemoptysis (n %)	6 (10.0%)
Cardiopulmonary Risk Index	
0 (n %)	9 (15%)
1 (n %)	23 (38.3%)
2 (n %)	15 (25.0%)
3 (n %)	9 (15.0%)
4 (n %)	3 (5.0%)
5 (n %)	1 (1.7%)
ASA class	
1 (n %)	5 (8.3%)
2 (n %)	17 (28.3%)
3 (n %)	13 (21.7%)
4 (n %)	21 (35.0%)
5 (n %)	4 (6.7%)
CXR	
Abnormal (n %)	53 (88.3%)
Etiology of restriction	
Obesity (n %)	4 (6.7%)
Diffuse parenchymal lung disease (n %)	16 (26.7%)
Bronchiectasis (n %)	3 (5%)
Neuromuscular diseases (n %)	1 (1.7%)
Heart failure (n %)	7 (11.7%)
Pleural pathologies (n %)	16 (26.7%)
Kyphoscoliosis (n %)	1 (1.7%)
Diaphragm hernia (n %)	2 (3.3%)
Atelectasis (post-obstructive) (n %)	2 (3.3%)
Mass lesions (n %)	7 (11.7%)
Radiation pneumonitis (n %)	1 (1.7%)
FEV1, % predicted (mean ± SD)	60.9 ± 10.7
FVC, % predicted (mean ± SD)	60.8 ± 10.6
FEV1/FVC, % predicted (mean ± SD)	84.0 ± 5.3
Total lung capacity, % predicted (mean ± SD)	61.3 ± 13.1
Residual volume, % predicted (mean ± SD)	59.8 ± 15.5
T_{LCO}, % predicted (mean ± SD)	56.9 ± 14.0

Table 2: The incidence and aetiology of postoperative pulmonary complications.

Early postoperative pulmonary complication	
(+) (n %)	6 (10.0%)
(-) (n %)	54 (90.0%)
Late postoperative pulmonary complication	
(+) (n %)	7 (11.7%)
(-) (n %)	53 (88.3%)
Postoperative pulmonary complication in first 7 days	
Atelectasis (n %)	2 (3.3%)
Pneumonia (n %)	2 (3.3%)
Pneumothorax/Pneumomediastinum (n %)	1 (1.7%)
Respiratory failure (n %)	1 (1.7%)
Total postoperative pulmonary complication in first 30 days	
Atelectasis (n %)	2 (3.3%)
Pneumonia (n %)	2 (3.3%)
Pneumothorax/ Pneumomediastinum (n %)	2 (3.3%)
Respiratory failure (n %)	1 (1.7%)

Table 3: The comparison of demographic and clinical characteristics of study group.

	POPCs(+) (n:7)	POPCs(-) (n:53)	P
Gender			
Female (n %)	3 (42.9%)	21 (39.6%)	0.87
Age (years) (mean ± SD)	47.6 ± 19.3	51.0 ± 14.9	0.66
Cigarette (package/year) (mean ± SD)	34.3 ± 53.4	20.6 ± 26.8	0.53
Current Smokers (in last 8 weeks) (n %)	3 (42.9%)	23 (43.4%)	0.98
FEV1, % predicted (mean ± SD)	64.5 ± 8.3	60.5 ± 10.9	0.28
FVC, % predicted (mean ± SD)	65.11 ± 8.7	60.2 ± 10.8	0.21
FEV1/FVC, % predicted (mean ± SD)	83.5 ± 6.1	83.9 ± 5.4	0.57
Total lung capacity, % predicted (mean ± SD)	62.7 ± 13.7	61.1 ± 13.1	0.78
Residual volume, % predicted (mean ± SD)	62.9 ± 14.5	59.4 ± 15.7	0.58
T_{LCO} % predicted (mean ± SD)	60.1 ± 10.3	56.5 ± 14.4	0.42
Arterial blood gas analysis			
pH (mean ± SD)	7.38 ± 0.2	7.36 ± 0.35	0.25
pCO_2 (mean ± SD) mmHg	36 ± 6.9	35.18 ± 5.87	0.79
PaO_2 (mean ± SD) mmHg	67.1 ± 6.9	77.4 ± 14.9	**0.01**
HCO_3 (mean ± SD) mmol/L	26.6 ± 5.0	25.4 ± 4.2	0.59
Cardiopulmonary Risk Index			
<2 0 (n %)	42 (57.2%)	28 (52.8%)	
2 (n %)	2 (28.6%)	13 (24.5%)	0.65
>2 (n %)	1 (14.3%)	12 (22.7%)	
ASA class			
1 (n %)	0 (0%)	5 (9.4%)	
2 (n %)	2 (28.6%)	15 (28.3%)	
3 (n %)	2 (28.6%)	11 (20.8%)	0.53
4 (n %)	2 (28.6%)	19 (35.8%)	
5 (n %)	1 (14.3%)	3 (5.7%)	
CXR			
Abnormal (n %)	7 (100.0%)	46 (86.8%)	0.31
Etiology of restriction			
Obesity (n %)	0 (0.0%)	4 (7.5%)	
Diffuse parenchymal lung disease (n %)	3 (42.9%)	13 (24.5%)	
Bronchiectasis (n %)	1 (14.3%)	2 (3.8%)	
Neuromuscular diseases (n %)	0 (0%)	1 (1.9%)	
Heart failure (n %)	0 (0%)	7 (13.2%)	0.62
Pleural pathologies (n %)	1 (14.3%)	15 (28.3%)	
Kyphoscoliosis (n %)	0 (0%)	1 (1.9%)	
Diaphragm hernia (n %)	0 (0%)	2 (3.8%)	
Atelectasis (post-obstructive) (n %)	0 (0.0%)	2 (3.8%)	
Mass lesions (n %)	2 (28.6%)	5 (9.4%)	
Radiation pneumonitis (n %)	0 (0.0%)	1 (1.9%)	

All operation were under general anesthesia, each patient have had pain relief. The mean FVC % predicted and TLCO % predicted were 60.8 ± 10.6 and 56.9 ± 14.0 respectively. Half of the patients have had severe restrictive PFTs.

The incidences of early and late POPCs were 10% and 11.7% respectively. The etiologies of POPCs are listed in Table 2. All patients were alive at the end of the follow-up period (30 days).

When the patients with and without POPCs compared, the demographic, clinical characteristics, smoking history, PFTs and the preoperative risk indexes were similar. However, the preoperative arterial partial oxygen pressure (PaO_2) were lower in patients with POPCs ($p<0.05$) (Table 3). According to the ROC analysis, $PaO_2 \leq 68$ mmHg was a risk factor for POPCs with 71% sensitivity and 76% specificity. (80% AUC and 95% CI, $p<0.05$).

The incidence of POPCs were comparable among surgery sites, open/laparoscopic surgery and surgery duration (p=0.56, 0.69 and 0.43 respectively). POPCs were developed in 42% of laparoscopic and 57.1% of open surgeries (p: 0.69). POPCs were developed after thoracic (71.4%), upper abdominal (14.3%) and neck (14.3%) surgeries. The mean duration of surgery was similar in terms of POPCs (1.5 ± 0.8 and 1.8 ± 1.5, respectively) (p: 0.43). The cardiopulmonary risk indexes, ASA classes and the etiology of restriction was not a significant risk factor for POPCs in this study. All the patients with POPCs had an abnormal CXR.

Discussion

For the first time, this study reported the incidence of early and late POPCs as 10% and 11.7% in restrictive pulmonary disorders. We indicated that a cut-off value ≤ 68 mmHg for preoperative PaO_2 is an independent risk factor of POPCs. Surgery site, duration of surgery, age, previous or current smoking, preoperative PFT results, physical status, cardiopulmonary risk points, abnormal chest radiography were not significantly related with an increased risk in our study.

The frequency of POPCs in the current literature ranges between 0.2% to 42% independent from the PFTs [4,9,10]. In an early descriptive report, the incidence was 35% following upper abdominal surgery [11]. In another retrospective observational study which included 898 patients who underwent laparoscopic gastric/colorectal surgery; it was 13% [12]. Another large multicenter prospective study which enrolled non cardiothoracic surgery with high risk patients reported the frequency of POPCs as 33.4% and deemed in increased mortality and longer hospital stay [13]. The possible reasons of this wide range may be the heterogeneity of populations included, the different definitions used and the type and site of surgeries. As well, with the improvement in anesthetical applications, intraoperative ventilation practices and surgical procedures, the frequency of POPCs decreased in years gradually [9,10]. Thus, a recent report with thoracic and upper abdominal surgeries which are well known risk factors for POPCs, 11.5% of 314 patients who had thoracic or abdominal resection (half of them were laparoscopic) developed POPCs [14]. However, none of these reports specifically evaluated PFTs.

Evaluation of pulmonary functions tests in predicting POPCs is not novel. In a prospective cohort study with COPD patients the incidence of POPCs was 24.4% and the severity of airflow limitation was strongly associated with increased POPCs risk in COPD patients [15]. A more recent trial which focused on obstructive pulmonary disorders indicated the frequency of POPCs as 8.6% in asthma and 7.9% in COPD patients. Large prospective studies performed with national databases, any postoperative complication (not only pulmonary) rate was reported as 25.8%. As well, COPD was independently associated with longer hospital stay, higher morbidity and mortality rates and also with higher postoperative pneumonia, respiratory failure [16,17]. In another previous report performed

in our department, Kocabas et al. revealed the higher frequency of POPCs in patients with a heterogeneous group of abnormal PFTs (45.2, 24.1% in normal and abnormal PFT groups, respectively) [11]. However, only 29% of this study group had restrictive PFTs.

Although there are no previous reports which specifically evaluate the incidence and risk factors of POPCs in restrictive pulmonary disorders, a few studies reported the rates in specific etiologies. In a small retrospective study with extremely severe scoliosis patients with varying severity of restriction, the frequency of POPCs was 15% which was correlated with the severity of restriction [18]. In comparison with their counterparts with normal PFTs, obese patients with restrictive pulmonary disorders have developed POPCs more frequently in bariatric surgeries [18]. The incidence of POPCs after vertebral surgery was 25% in a small retrospective study of pediatric patients with scoliosis and FVC<40 [19,20]. However, none of the studies used standardized spirometric methods. Herein, we specifically focused on restrictive pulmonary disorders defined according to standardized European Respiratory Society/American Thoracic Society (ERS/ATS) criteria and have showed that the incidences of both early and late POPCs are as high as the obstructive pulmonary disorders.

Predicting the POPCs is critically important. Preoperative spirometry has been used in several reports to predict POPCs as it is rational to use a non-invasive, convenient and rapid diagnostic test. In a systematic review which included large studies, abnormalities on spirometry were found to predict postoperative pulmonary complications in only trial evaluating either of these tests. This small trial of patients undergoing head and neck surgery showed spirometry, especially FEV1; to be predictive of POPCs only in a univariate analysis but it did not reached statistically significance in multivariate analysis [21]. Another study of upper abdominal surgery patients showed that patients with abnormal preoperative PFT results had much more POPCs than with normal PFT result (45.2% *vs.* 24.1% respectively) [11]. ACCP guideline recommends obtaining PFTs for patients with COPD or asthma and for patients with dyspnea or exercise intolerance that remains unexplained after clinical evaluation. The guideline also refuses to use of PFTs to deny any surgery with the exception of lung resection surgery [6]. However, current guideline has no recommendation on patients with restrictive PFTs. In this study, PFT results were not associated with the risk of POPCs probably due to the small study sample size.

There is conflicting data about the necessity of preoperative arterial blood gas analysis in prediction of POPCs. In a large multicenter study which included patients who underwent both general and regional anesthesia. In addition, lower preoperative arterial oxygen saturation was showed as the strongest patient related risk factor of POPCs [22]. So the authors concluded the results as the measurement of oxygen saturation was a cost-effective and externally validated method [23]. Several other studies which focused on hypercarbia failed to show any independent association with POPCs. Nevertheless, none of these reports mentioned PFTs. According to the best of our knowledge, there is no previous data which investigates arterial blood gas analysis as a risk factor of POPCs in restrictive PFTs. Preoperative PaO_2 value ≤ 68 mmHg would be a clue for predict POPCs with 71% sensitivity and 76% specificity of AUC 80% in restrictive pulmonary disorders.

In fact, it's quite problematic to evaluate restrictive pulmonary disorders as a risk factor of POPCs since they are a heterogeneous group of disorders. In general all of them are characterized by reduction in lung volumes especially in forced vital capacity and decreased compliance on PFTs, with preserved expiratory flow. Several complex mechanisms play role in development of POPCs in restrictive disorders. The decrease in vital capacity, marked changes in regional ventilation, restriction of lung expansion and diaphragm dysfunction are the main reasons. With the effect of the postoperative pain, reduced central stimuli of respiration, prolonged duration of anesthesia and disuse of neural blockade, it's not surprising to face the augmented incidence of POPCs in these patient groups [24-26].

According to our study, the most common POPCs including atelectasis, pneumonia, and pneumomediastinum were similar to the literature. Respiratory failure was developed in only 1.7% of the study group. The most common POPCs are respiratory failure in many studies (4.7%), followed by pleural effusion (3.1%), atelectasis (2.4%), pulmonary infection (2.4%), bronchospasm (0.8%), pneumothorax (0.6%), and aspiration pneumonitis (0.2%) [23,27]. The most common POPCs was respiratory failure-pleural effusion-pneumonia and prolonged oxygen need-atelectasis among different surgery sites regardless of PFTs. Bronchospasm, pneumonia/atelectasis and respiratory failure was the most common POPCs in asthmatics and pneumonia/atelectasis in COPD patients.

This study has several limitations. The main limitation is the relatively small sample size which may affect precision of the estimates and underestimation of some differences of means in terms of p value. However, we know that the incidence of restrictive PFTs is about 8% to 12% [28]. Secondly, this study included all surgeries under general anesthesia which may be concluded as a limitation. Finally, attending physicians were not blinded to PFT results that may have introduced information bias to the study.

In conclusion, this prospective descriptive study throws fresh light into the incidence and risk factors of early and late POPCs in restrictive pulmonary disorders. To the best of our knowledge, this is the first trial which specifically focused on this topic to date. Lower PaO_2 at the preoperative period would be a clue for predicting POPCs in restrictive pulmonary disorders. Further trials with larger cohorts would lead to better identification and develop preventive measures in these patient groups.

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